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Review on the energy and renewable energy status in Iraq: The outlooks

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ABSTRACT

An outlook into the country profile at the existing electricity generation with crude oil production at the present level with accompanying gas flares cause CO_2 emission as well as the industrial, human activities and the grid electricity distribution has been accounted for. The estimation of solar radiation levels as well as its productivity in terms of photovoltaics (PV's), concentrated solar powers (CSP) and chimney towers have been paid for others renewable energies; wind, tidal and geothermal productivity. A selection of possible site for installation according to the given geographical hazard and the maximum solar radiation could be collected. An overview for futuristic demands and possible solar energy supply that could be generated has reviewed. Furthermore, the desalination of underground or polluted water to support the solar system as well as the needed plantation to preserve a clean and green environment and low dust climate is presented.

Contents

1. Introduction

Most of the Arabian Peninsula countries have not adopted solar energy due to the fact that oil is relatively cheap and easily accessible. There are no incentives to look for alternative forms of energy at this time. In addition, protecting the environment is not a top priority in the region due to extracting and marketing oil worldwide does need investment in the renewable energy. However, Iraqi government and people are not fully aware of the importance of renewable energy, so developing renewable energy technology in the region is primarily and a result of individual's initiatives and non-governmental organizations instead of official policy. During the last decade, the energy question has arose in a multidimensional questioneering. As far as the abundance of fossil fuel energy of oil but energy thirst has started in Iraq since 1991 due to disruption of full scale destruction on this country. The fossil fuel is not limitless though in the next hundred

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years will be vanished, the only continuous resource is the solar energy as a solution to hinder the CO_2 emission from various sources of fossil and biofuel. The solar energy requires an immediate attention due to the climatic change that effects the global warming [1]. The 233 petawatts of sunlight reaching the Earth's surface are plentiful compared to the 24 terawatts of average power consumed by mankind every year [2]. The world deserts have received sunlight energy within 2 h, more than mankind consumes a year [3]. The western Iraq desert has the highest solar electricity generation power among the others in the region, as the global mean of 170 W/m^2. The Iraq deserts alone generate a mean power density of 270–290 W/m^2, and reaching a peak power density of 2310 kwh/m^2/year according to The German Aerospace Center (DLR) [3,4]. This is given Iraq a hand to remain an energy supplier in the future as well as present supplier of energy in the form of fossil fuel.

Kazem and Chaichan [5] have investigated the electricity shortages and many challenges in Iraq. This investigation has found that solar, wind and biomass energy are not being utilized sufficiently at present, but these energies could play an important role in the future of Iraq's renewable energy. Additionally, the potential of offshore-wind energy in the Gulf (near Basrah in the southern part of Iraq) needs to be investigated. They have mentioned, discussed and reviewed the Iraqi government's attempts of utilizing renewable energy. While, Dihrab and Sopian [6] have elaborated the renewable resources in the last two decades due to persisting energy demand coupled with decrease in fossil fuel resources and its environmental effect to the earth. In Iraq, the electric power generated is not enough to meet the power demand of domestic and industrial sectors. They have proposed a hybrid system as a renewable resource of power generation for grid connected applications in three cities in Iraq using MATLAB solver, in which the input parameters for the solver were the meteorological data for the selected locations and the sizes of PV and wind turbines. Their results have showed that it is possible for Iraq to use the solar and wind energy to generate enough power for some villages in the desert or rural area. Other side, an attempt was made to study and examine some aspects of radiation climatology which are important in solar energy utilization by AL-Riahi and AL-Kayssi [7]. The yearly cumulative global radiation for Baghdad is (2160–7000) MJ/m^2 per year. While, the annual total of daily diffuse radiation at Baghdad is about (600–700) MJ/m^2. Over the year, the highest UV radiation received during June and July (243 Wh/m^2) and the lowest in December (79 Wh/m^2). Furthermore, UV radiation constituted on average 3.25% of global radiation. AL-Riah et al. [8] have studied the climatology of global solar radiation for assessing the potential efficiency of systems designed for solar energy utilization. They have analyzed the monthly averages global solar radiation and the general atmospheric transparency for the period 1971–1985 for three different climatological zones (Mosul, Baghdad, Nasiriyah), where the percentage number of days with solar radiation and sunshine duration values below a certain value is discussed.

Since 1950 the production of oil and its flares from the oil production activity as well as the human industrial activity and the CO_2 emissions have increased. Due to the disruption of the electricity power plants since 1991, a harmful emission of CO_2 from small scale public generators has added further pollution to the environment. The only remaining at its minimum level is the activity of much dependent on biofuel in the rural areas and villages. The aim of this study is to review the latest Iraq potential in production of oil and gas that lacking infrastructure in many ways. Also, to present the potential of renewable energy as a replacement valuable clean source together with an adaptable water desalination that can replace the future shortage in the incoming decades. This study is divided into the followings: section researches the solar energy in Iraq. The energy consumption leads to pollution, distribution network, different power availability followed by future trends of renewable energy are given in Section 3. Finally, conclusion is furnished clearly in Section 4.

2. The alternative solar energy in Iraq

The republic of Iraq is located at the south-west of Asia, to the north-east of the Arab homeland. It is bounded on the north by Turkey, on the east by Iran, on the west by Syria, Jordan and Saudi Arabia, on the south by Kuwait and Saudi Arabia. Iraq lies between latitudes 29 5′ and 37 22′ north, and between longitudes 38 45′ east and 48 45′. The area of Iraq is 435052 km^2. The north of Iraq consists of mountains type where the sunny days are not like in other regions of the country especially in winter time. The middle part of Iraq is mainly a plane ground between two main rivers; Tigers and the Euphrates, where sunshine is more than in the north. The southern part of the country is an area of outstanding pure atmosphere except when there is a dusty-storm from desert; otherwise this area can be considered as one of the world maximum solar radiation regions. Many authors [9–16] have investigated the global solar radiation that is available in Iraq. The calculation based on the Angstrom method [17–20] depends largely on sunshine duration humidity, maximum and minimum temperature. Abdul-Wahid and Hassan [21] have studied different sites, those are in the south includes Al-Basrah, Al-Nasriya, Al-Samawa, and Al-Amara, the middle consists of Baghdad, Haditha, Al-Rutba, Kerbala, Al-Hai, Al-Najaf and Al-Diwaniya and the north includes Kirkuk, Khanaqin, Sulaymania, Al-Mosul and Zakho and the net solar radiation is shown in Fig. 1. It is observed that the net radiation in south and middle regions is higher than in north of Iraq. Calculations of the net solar radiation were carried out based on the following input parameters: sunshine duration, cloud cover, relative humidity, the maximum and minimum temperature variations, ground albedo, sun-earth distance, and incoming and outgoing global solar radiation. The monthly average daily solar radiation on horizontal surface and radiation competent were recorded and documented [22].

The result of calculations has showed that the average of total annual radiation for the southern sites is 7263.97 MJ m^{-2} per year larger than for the northern sites 6318.83 MJ m^{-2} per year as given in Table 1. Abed and Mohammed [16] have presented analysis of solar radiation, and sunshine duration for the period of 1977–2000 at three sites, Tikrit, TuzKurmato and Kirkuk. Moreover, the analysis of the locations shows that the maximum values of radiation are observed in May, June and July, while the minimum values appeared in January, February, November and December as presented in Table 2. The monthly mean of daily solar radiation, sun shine duration, maximum temperature and relative humidity were obtained from the archives of Iraqi meteorological office [10]. The data have covered five years of daily data for Baghdad, Mosul and Rutba which represented middle, north and west of Iraq. The results are presented in Table 3, it is observed that the highest radiation is at June, July and August, while January and December are lowest one. While, Table 4 shows the results of estimated Sunshine and global solar radiation of three site located at north and west of Iraq; Haditha, Beji and Samara, where the results have been estimated for a period of 17 years [12].

Tables 2–4 summarize the global solar radiation measurements on horizontal surfaces that have the maximum values at all considered locations appear in June, while the minimum values were in December, the annual average daily values for the global solar radiation on horizontal surface at Baghdad is 18.57 MJ/m^2/day, at Mosul is 14.75 MJ/m^2/day and at Rutba is 18.53 MJ/m^2/day. The maximum temperature has higher values in July and lower in December and January using direct measurement [13,16]. In most of calculations or measurements available concerning the north,

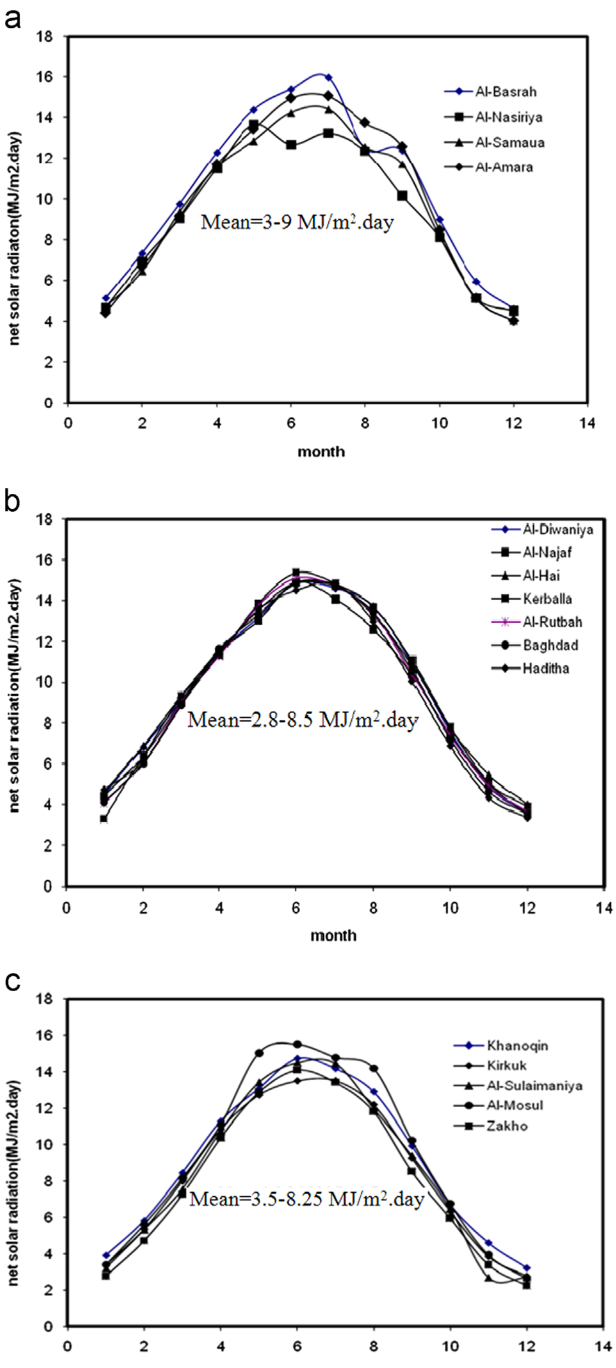

Fig. 1. The net solar radiation (a) (south of Iraq), (b) (middle to west of Iraq) and (c) (north of Iraq) [21].

the middle and south of Iraq have an averaged from 16 to 10 MJ/m^2/day for 5 month in the north, 6 month in the middle and southern region, respectively. But in western desert of Al-Anbar district all most have 8 month of sunshine duration while the lowest is over 4 MJ/m^2/day. This energy is quite sufficient to drive all the photovoltaics (PV's), concentrated solar power (CSP) and all houses hold facilities of heating, cooling and water distillation along the year.

Table 1
Republic of Iraq Meteorological Office (RIMO). The measured values in a period 1961–1992 for all stations [16].

No.	Location	Latitudes (N)	Elevation (m)	The annual solar radiation MJ/m^2 year
1	Al-Basrah	30° 31′	2.4	6835.46
2	Al- Nasiriya	31° 01′	3	7263.97
3	Al-Samaua	31° 16′	6	7123.67
4	Al-Amara	31° 50′	7.5	7021.23
5	Al-Diwaniya	31° 57′	20.4	7021.23
6	Al-Najaf	31° 57′	50	7135.2
7	Al-Hai	32° 08′	14.9	7030.82
8	Kerballa	32° 34′	29.0	7185.74
9	Al-Rutbah	33° 02′	615.5	7114.44
10	Baghdad	33° 18′	34.1	6997.46
11	Haditha	34° 08′	108	6662.75
12	Khanoqin	34 °21′	202.2	6556.3
12	Kirkuk	35 °28′	330.8	6660.17
14	Al-sulaimaniya	35° 32′	853.0	6727.42
15	Al-Mosul	36° 19′	222.9	6318.83
16	Zakho	37° 08′	442	6835.46

Table 2
Sunshine and global solar radiation estimated from measured metrological data estimated values for a period of 1977–2000 [10].

Month	Kirkuk (35.30°N, 44. 21°E)		Tikrit (34. 35°N, 43.37°E)		TuzKhurmato (34.88°N, 44.64°E)	
	Sunshine $_h$	MJ/m^2 day	Sunshine$_{h.}$	MJ/m^2. day	Sunshine$_h$	MJ/m^2 day
JAN	6.252	13.71	5.879	10.14	6.430	13.08
FEB	7.008	18.42	6.682	13.67	7.630	18.21
MAR	7.892	23.03	7.332	17.58	8.590	23.38
APR	9.364	27.93	8.303	21.16	9.900	27.11
MAY	11.16	30.35	9.555	24.80	12.26	29.86
JUNE	11.09	30.23	11.235	28.47	11.98	30.71
JULY	11.09	27.79	10.947	27.90	11.80	28.26
AUG	10.19	22.18	10.575	25.53	10.33	23.45
SEP	8.320	16.93	9.370	21.61	8.540	17.40
OCT	6.608	12.03	7.825	16.66	6.460	12.07
NOV	5.280	9.52	6.400	11.18	4.830	9.51
DEC	6.252	13.71	5.255	9.38	6.430	13.08

Table 3
Sunshine and global solar radiation estimated from measured metrological data estimated values for a period of 2004–2008 years [10].

Month	Baghdad 33.22N°, 44.23E°		Mosul 36.32N°, 43.15E°		Rutba 33.03N°, 40.28E°	
	Sunshine	MJ/m^2 day	*Sunshine*	MJ/m^2 day	*Sunshine*	MJ/m^2 day
JAN	5.7	10.6	4.6	6.9	6.0	9.2
FEB	6.7	13.33	5.0	9.9	8.8	15.5
MAR	7.9	17.7	5.8	13.4	8.4	18.6
APR	9.9	21.6	8.1	17.7	7.9	21.7
MAY	10.1	23.4	10	19.9	9.5	23.4
JUNE	12.6	27.0	12.3	22.8	11.7	25.9
JULY	12.3	26.0	12	21.3	12.3	25.2
AUG	12.1	24.6	11.8	21.0	11.2	24.9
SEP	10.5	20.8	9.7	18.0	10.3	22.3
OCT	9.2	15.8	7.5	12.4	9.2	15.3
NOV	7.7	11.9	4.3	7.7	7.3	10.9
DEC	6.3	9.8	4.2	5.3	6.0	9.9

3. The country profile on energy consumption

Iraq is the birth place of civilizations as the manufacturing of bricks tile plates, cooking pots, jars, the time recording, maths, the zero and Arabic numeral writing letters, the wheel, the crate, knives, swords, the war and agricultural tools, weaving and clothing. Since the energy depends much on woods, straw and olive oil which are of natural sources.

Table 4
Sunshine and global solar radiation estimated from measured data. (1995–2012) [12].

Month	Haditha		Beji		Samara	
	Sunshine	MJ/m^2 day	*Sunshine*	MJ/m^2 day	*Sunshine*	MJ/m^2 day
JAN	5.875	11.91	5.765	9.64	5.876	8.41
FEB	7.229	15.64	6.529	12.84	6.9	10.78
MAR	7.954	20.89	6.988	16.75	7.614	14.67
APR	8.379	26.25	7.871	21.38	8.71	16.21
MAY	9.992	30.3	9.041	24.05	9.962	19.81
JUNE	11.95	31.83	11.382	27.01	11.033	21.45
JULY	11.942	31.86	11.265	26.72	10.652	21.9
AUG	11.408	29.44	11.029	24.89	10.224	20.57
SEP	10.267	25.43	10.047	21.31	8.929	17.69
OCT	8.558	19.37	8.135	15.94	7.867	12.78
NOV	7	14.46	6.294	11.65	6.452	9.31
DEC	5.792	10.63	5.318	8.96	5.29	7.5

Since the discovery of oil in the 1920s, most of the produced oil was exported. Until 1950s and late 1960s, a little portion of oil finds its way for local uses in transport and generating electricity. In the 1960s and 1970s, an industrial activity has started in fields of producing cement and brick manufacturing. While no major transport project being started except the old Gulf-Europe single track rail road. The industrial activity solely truck transports has increased the liquid fuel consumption and the individual transports. This is shown in Fig. 2 for energy consumption.

3.1. CO_2 emissions in Iraq

CO_2 emissions from gaseous fuel consumption in Iraq were 3.42% of total as for 2008. The highest value over the past 48 years was 16.08 since 1964, while its lowest value was 1.21 in 1968 [26]. This consumption can be relatively related as shown in Fig. 3, given in Table 5 and supported by Fig. 4a, as observed an increased demand on transport and the population growth since 1960. Moreover, due to the disruption occurred in 1991, the production of flares, petrochemicals, cement, Fertilizer and glass have contributed to CO_2, while currently can be assumed solely to private motor transport and electricity generating.

Otherside, the oil production and its local consumption depend largely on the stability geographically and geopolitically as well as the political motivation which rest not only on national interest but on motivated notion from outside and inside lobby of interest, this is clearly indicated in Fig. 4b and c, Tables 6 and 7. Meanwhile, the total production of oil is given in Table 8 but the gas goes into flares unless piped into liquefaction as used locally and for exportation.

3.2. The status of grid distribution networks

During the period of 1991 till 2003, the grid distribution is being parallelized by destruction due to disruption or sabotage. Thus network is aging and unsuitable to sustain excessive power loading and massive losses due to vice versa power handling as well as it requires complete modernization that should be replaced by a robust smart grid instead of just additional problematic over loading.

The smart grid is based on concept of consumer grid power generating distribution interaction as well as measuring and balancing the state of power loading during peak hours and managing the power state for each district or user requirement. The smart grid is to handle power from various sources of energy generating plant which either from fuel, gas or PV as well as CSP and others. It is time to replace the existing with a new smart grid that self-intelligence to manage the power distribution as well as

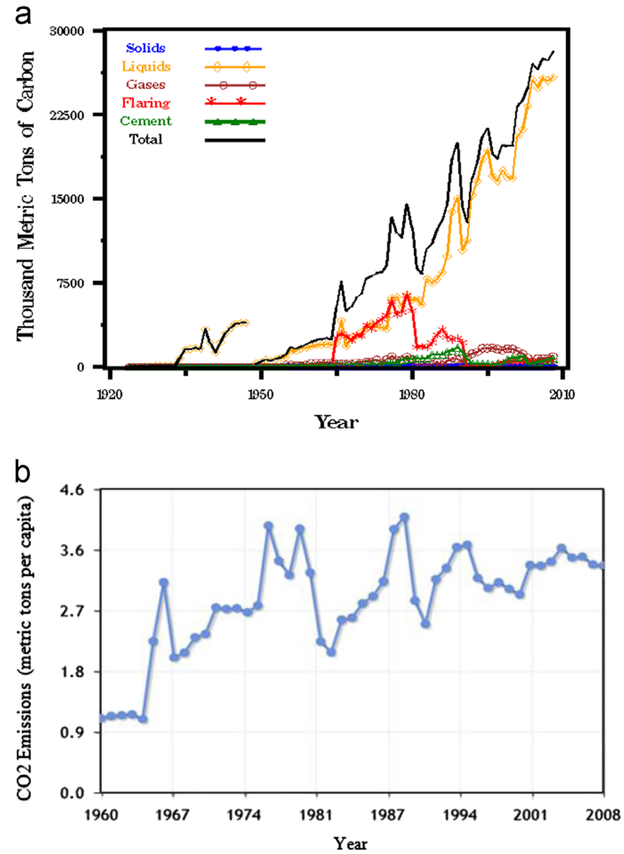

Fig. 2. (a) Carbon dioxide emissions (CO_2) and (b) Variation of CO_2 emissions (metric tons of CO_2 per capita) [34].

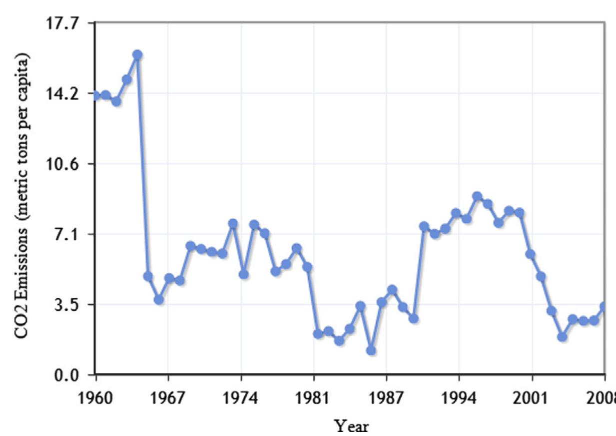

Fig. 3. Variation of CO_2 emissions from gaseous fuel consumption (% of total) in Iraq [26].

consumption and accordingly integrate the renewable generated power into the grid [23,24].

3.3. The geographical site for solar collector installation

For considering solar system, a large areal coverage, a need for geographical assessment for the best radiation density and the various geographical hazards that affect these installations are required. These geographical hazards are being assessed by either its occurrence or locality according to the nature of soil or manmade activity [23,25]. They have recognized these hazard into 15 classification which are: 1- Floods, 2- Earthquakes, 3- Mass movements, 4- Karstification, 5- Depressions, 6- Gypcrete, 7- Swelling clays, 8- Pollution, 9- Gypsum

Table 5
Energy consumption by sector for (1999–2012). (in thousand metric tons of oil equivalent) [26].

Technology	Transportation	Agriculture	Commercial &public services	Residential	Non-energy uses and "other" consumption	Total final energy consumption
6333 – 6% yearly increase	9087 – 6% yearly increase	unknown	unknown	2290 – 5% yearly increase	3300 – 5% yearly increase	21,011 – 6% yearly increase

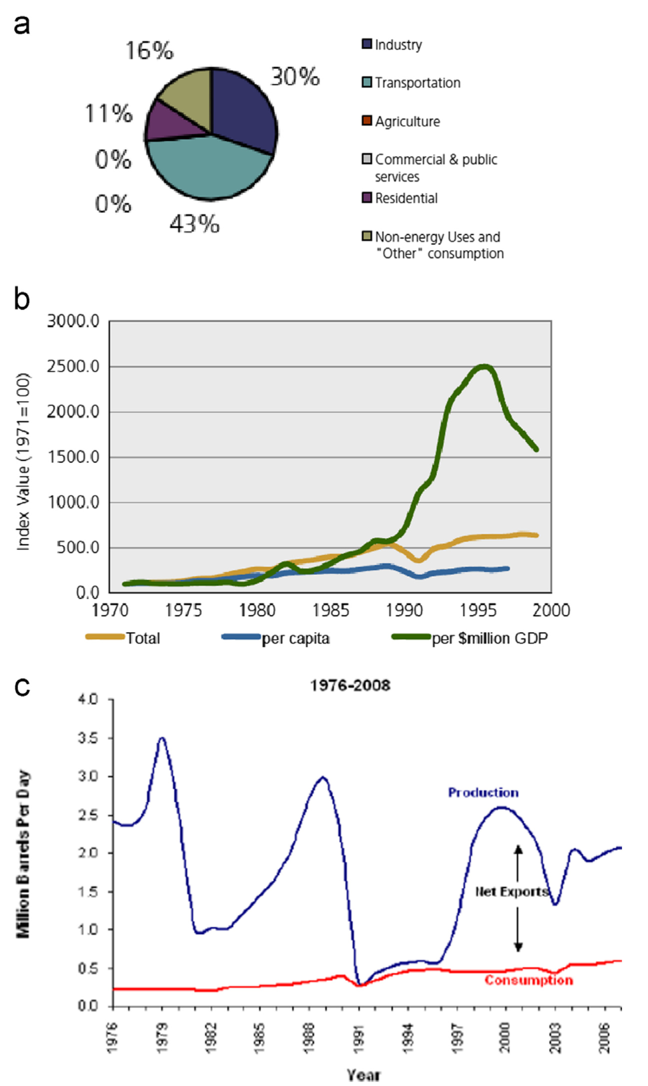

Fig. 4. (a) Energy consumption by sector, Iraq, 1999 which is a stable period in consumption. (N.B. Due to the increasing demand on private light duty cars a projected increase in total fuel consumption 6% yearly). (b) Energy consumption: relative trends, Iraq, 1999 and (c) Iraq petroleum production and consumption [26].

induced hazards, 10- Tectonic active areas, 11- Sand dunes, 12- Marshes (Organic soils), 13- Sabkhas, 14- Mining disasters and 15- Sea water intrusion. These hazards are scaled up in Table 9. The lowest hazard is located in the western boarded quadrangle as from Sinjar, Sur, Wadi Al-Myah, Rutba,Wadi Horan, Wadi Tibil, Al-Thurthar, Al-Breet, Al-Ma'aniya, Al-Salman, Ansab and Al-Rukhaimiya.

Furthermore, the mentioned areas are of desert climate with few dry river which flooded in winter and dry in summer which require provision for a rainfall collecting dams along these dry valleys (Wadi such as Wadi Almyah, Horron, Wadi Tibil and Wadi Al-Therthar), the smaller valleys also can be considered. The sacristy of water requires higher attention in collecting these resources of water which is only available over short periods seasonally. Moreover, the available dust storm can move the sand dunes and reduce visibility and sunshine duration which requires rehabilitation of this part of the desert which is very low populated by implantation a group of plants which is suitable for these type of climate mainly the hahoba, olive trees, and date palms to hinder the dust storm and producing biodiesel and olive oil on the other side. A survey for all the targeted areas with solar energy potential (2000 kWh/m^2/year for CSP and for PV 2050 kWh/m^2/year which is equivalent to 1–2 barrels of fuel oil/m^2 yearly) should have slopes not greater than 3% and roughness within 1% to have continuity for at least more than 10 km^2 to accommodate the installation of CSP and may be larger for PV and chimney type generator for low cost development. Also, water dam on these valleys is serving as energy recycling during the night or cooling the CSP plants. CSP has major setback that requires a small heat collecting area at alleviated temperature, can be solved using nanofluid capables to enhance the heat transfer within order of magnitude. The fluid surveys at high boiling point with high heat transfer, which exceeds copper thermal conductivity by 6 and 12 times for diamond and borazon (boron nitride), respectively [26,27]. An innovative novel solution of de Risi et al. [28] is represented by solar transparent through collector with gas based nanofluid found to be a solution for minimizing the receiver collector area at the mixture of nanoparticles with adhered gas to compensate the relative low heat transfer coefficient which is a compensation of an increases exchange surfaces.

3.4. Scenario and outlook of electrical power supply in Iraq

It is quite clear that electrical power supply and generation have been running short of demand since 1991 onward. The solution is to invest heavily into solar power generating technology to solve the mounting problem arose in the energy requirement at the present and for the future where full development in the infrastructure of the country are required in many aspects which demanding an immediate solution. The transport and high ways are to reduce CO_2 and flares that coincide with the crude oil production. An infrastructure of both oil production and gas utilization, oil transport and marketing also require massive electrical energy as well [23]. The criteria of using solar power is the best solution in term of investment in such power system in order to gain saving instead of investing huge amount of money in both oil or gas power generation where the solar power and its storage facilities are a solution to reduce CO_2, maintain a clean power for the future and saving in investment.

The solar power generation at the level of incoming sunshine is one of the highest demand in the world, then the geographical site preliminary being suggested according to the geographical survey to fulfill the goal of having more than 200 GW or more via various available technologies to the renewable energy generating types as given Table 10. The technology that can be adapted for this country can be based on how suitable level of trained personal for installation and services for long period of operation. For both the CSP, thermal and wind energy require highly trained personal in operational maintenance and day to day services [11,12]. The others thermal parabolic tubular collector or chimney type is of

Table 6
Existing refineries in Iraq [25].

Refinery	Location	Capacity (bbl/d)	Notes
Baiji	North-Central Iraq	310,000	Improvement operational issues
Basrah	Near Basrah	150,000	Considering adding 70,000 bbl/d distillation tower
Daura	Baghdad	110,000	Considering adding 70,000 bbl/d distillation tower
Mosul-Qaiyarah, Krkuk, Khanaqin,K3 Haditha	Scattered	< 10,000 each	Topping plants making low-grade diesel and kerosene
Muftiah, Najaf, Maysan, and Nassiriyah-Samawah	Scattered	< 10,000 each	Topping plants making low-grade diesel and kerosene

Table 7
Planned new refineries in Iraq [26].

Refinery	Builder	Capacity (bbl/d)	Notes
Nassiriah	Foster Wheeler	300,000	Front end engineering and design contract
kerbalaKa	Technip	150,000	Front end engineering and design contract
Kirkuk	Shaw and Webster	150,000	Front end engineering and design contract
Maysan	Shaw and Webster	150,000	Front end engineering and design Contract
East Baghdad	N/A	100,000	proposed

Table 8
Distribution of oil reserves in Iraq [26].

Operating area	Fields	Reserves (billion bbl)	2010 production (1000 bbl/d)	Potential production (1000 bbl/d)
KRG	6	2	15	375
North oil company	32	21	770	1300
Midlands oil company	27	13	10	680
Missam oil company	10	8	110	820
South oil company	25	69	1455	10,050
Total	100	113	2360	13,225

lesser requirement for advanced training. In all these technologies the common disadvantages are all generated electricity depends on the day light availability and sunshine duration.

Thus storage facilities must be capable to store vast electrical or thermal energy that being generated. Accordingly a battery bank or heat sink is required to accumulate the generated energy or when the energy massive in needed to be acuminated by a recycling of hydropower. The advantage is due to its competitiveness as given in Table 10. Regarding the land issues which may require as much as 0.3% of total area of Iraq, the desert which is a low populated area can accumulates both CSP and thermal chimney solar generator, while the PV can be installed on the roof of all the city houses to the grid in the peak hours. However the disadvantage of the desert is the environmental dust storm [15]. This requires technical solution in installing a dust electrostatic repellent and an environmental solution as well. When one considers the CSP or thermal chimney solar power requirement for cooling water become eminent for every 1 MW that needs 8000 m^3 of water per year for cooling purposes. Moreover, this being estimated for the self-contained solar desalination that each 5 units can produce pure water of 1 million cubic meter of water and requires only an area of 10 km^2.

3.5. The hydropower availability and the status of productivity and electric power supply

However, the hydropower productivity shares only 1/3 of the total energy production but at present running at lower productivity due to lack of maintenance or electrical transfer line damages running now at 19%. The rate of production of the existing dams is given in Table 11. Further setback to the hydropower, all the main river suffer of water shortage supply are from the neighboring countries; Syria, Turkey and Iran. The lost supply of incoming water supply mainly the Euphrates, Tigers and Deyala are very high due to massive erecting of dams in neighboring countries. Although Al-Fatha dams being started in construction but at the state of disruption being halted at the time been having a design capacity at 2500 MW. The capacity data for the operational and planned hydropower stations were tabulated in Tables 11 and 12, respectively. For both the existing power plant and the hydropower forecast till 2050 are given in Fig. 5. It is cleared that the electrical power will running short of the growing demand at the present due to of foreseen shortage incoming water supplies from main rivers from the neighbor countries [25].

3.6. Scenario based on the assessment of European-middle east countries of various power source potential

A report [3] has assessed the renewable energy on various sources that may become a suitable energy replacement, of fossil and coal fuel in order to reduce the CO_2 emission and other harmful volatile gases to the environment to meet the Kyoto target. For an overall observation being set to various satellite data collection mainly geographical land scape, the normal sunshine on the ground level, the Biomass related to the ground cover and forestry, the wind speed distribution, the hydropower location, water resources and the geothermal location for all European and Middle East countries. The most important is the solar power being assessed and the hydropower altogether with the wind energy, biomass energy and geothermal energy. However, an isolated assessment for Iraq, it has been considered and highlighted. The assessment is based on the renewable technologies characteristic and what has to offer and its limitation as in Table 13.

The solarity of Iraq has shown and estimated earlier as shown in Fig. 6. The PV system can be used to supply isolated or in connection to grid as the capacity range from few KW's to hundred MW's. Batteries storage is usually applied for smaller decentralized supply systems, but for large PV system, it is up to 1.5 GW. This is due to fact that PV cannot offer any secured capacity but backup capacity must be provided by other technology within the grid [29]. Special hydropower pumps and storage of excess power is to be utilized for backup. The capacity factor is determined by dividing the actual output with the maximum possible output, i.e. a base load power plant with a capacity of 1000 MW might produce 648000 MW h in 1 month. The number of MWh that would have been produced at full capacity can be determined by multiplying the plants maximum capacity by the number of hours in the time period. 1000 MW × 30 days × 24 h/day is 720000 MW h. The capacity factor is determined by dividing the

Table 9
Occurrence of the geological hazards with their total scored weights (within the 35 quadrangles) [23–25].

Quadrangl name	Geological hazards																
	Floods	**Earthquakes**	**Mass movements**	**Karstification**	**Depressions**	**Gypcrete**	**Swelling clays**	**Pollution**	**Gypsum induced hazards**	**Tectonic active areas**	**Sand dunes**	**Marshes (organic soil)**	**Sabkhas**	**Mining disasters**	**Seawater intrusion**	**Number of Geological hazards**	**Total Scored Weight**
Zakho	2.5	2.5	6	2					2							5	15
Kani Rash	2.5	2.5	6	2												4	13
Sinjar	5	2.5	2.5	2				2	2							6	16
Mosul	6	6	7	6				9	4					4		7	42
Erbil and Mahabad	7.5	4.5	7.5	1.5				2	1.5	1.5						7	26
Sur	2.5		2.5	2					2		2		2			6	13
Qaiyarah	11	2.5	5	4	2.5	6		4	3		2		5			10	45
Kirkuk	10	2.5	4		2.5			10	1.5	1.5	2		2.5			9	35.5
Sulaimaniyah	9	9	9	4				4	2	1.5						7	
Wadi Al-Miyah andAlbu Kamal	5		2.5	4	2			4	2				2			7	21.5
Haditha	10		2.5	8	2	4		2	2	1.5	3		2			10	37
Samarra	9.5	3.5	2.5		2.5	3		7	1.5	1.5	4		2	3		11	41
Khanaqin	9.5	2.5	2.5	1.5				3	1.5	1.5				3		8	24
Sab'a Ebyar and Rutbah	7.5		5	2	2		5	3.5								6	25
H 1	5		3.5	5	2					1.5	2					6	19
Ramadi	7.5		2.5	2.5	2	2		7	2	2.5			4			9	32
Baghdad	11	7			2.5	6		4			4	2	2			8	38.5
Mandali	7	2	2	2				3	1.5	1.5	3					8	20
H 4 and Wadi Hauran	3.5		2.5	2	2		2									5	12
Wadi Tabil	2.5				2		2									3	6.5
Shithatha	7.5		2.5	1.5	3	2		2		1.5			2			8	22
Karbala	7.5		2.5		2	2			5			6	2			8	29
Kut	7.5	5		2.5	4		2	2			2	2				8	27
Ali Al-Gharbi	2.5	2.5	2.5		3			2			2					6	14.5
Muger Al-Naam andUbaidat	3.5				2		2									3	7.5
Birreet	2.5			2	2					1.5						4	8
Najaf	5		2.5	2	2	2		4		1.5	4		2			9	25
Nasiriyah	7.5				2			4		1.5	5	2	2			7	24
Amarra	4	2.5			2			4				6				5	18.5
Ma'aniyah	2.5			2	2											3	6.5
Salman	3.5			2	2											3	7.5
Sooq Al-Shiyookh	7.5			2	2			2		1.5	2	2				7	19
Basrah and Abadan	3	2.5			2.5	2		2			2	2	2		3	9	21
Ansab	2.5			2	2											3	6.5
Rukhaimiyah andKuwait	2.5			2	2											3	6.5

Table 10
PV land – area advantage [11,12].

Technology	Converter Efficiency (%)	Capacity Factor (%)	Maximum Packing	Land per year for: GW	Land per year for: GWh
Flat-Plate PV	10–20%	20%	25–75%	10–50 km^2/GW	5000–25,000 m^2/GWh
Wind	Low to 20% [23]	20%	2–5%	100 km^2/GW[20]	140,000 m^2/GWh[22]
Biomass	0.1% total		High-plants compete for sunlight	1000 km^2/GW[21]	500,000 m^2/GWh[22]
Solar Thermal or PV Concentrators	15–25%	25%	10–20%	20–50 km^2/GW[21,22] 20 km^2/GW [19]	10,000–20,000 m^2/GWh

Table 11
Operational hydropower dams [25].

Dams	Dokan	Derbedkhan	Mousil	Himreen	Haditha	Samara	A-hidya	Kuffa
Power **MW**	400	240	750	50	660	75	15	5

Table 12
Planned hydropower dams [25].

Dams	Bakhma	Taktak	Al-Khazer Comel	Badosh	Al-Baghdadi	Mendawa	Al-Udym	Al-Fatha
Power Mw	1500	300	24	171	300	620	27	2500

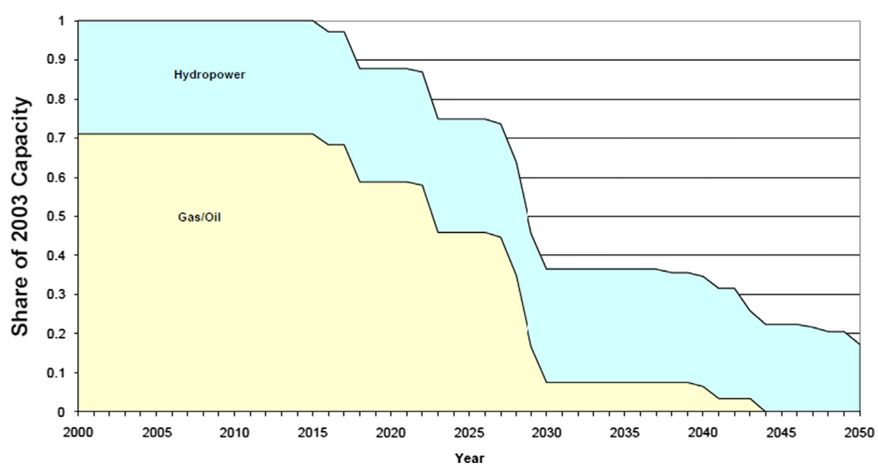

Fig. 5. Old power plants in Iraq since 2003. Total Capacity 2003 = 7148 MW [25].

actual output with the maximum possible output. In this case, the capacity factor is 0.9 (90%)

$$\text{capacity factor} = \frac{648000\ \text{MWh}}{30\ \text{day} \times 24\ h/\text{day}\ \times 1000\ \text{MW}} = 0.9 \approx 90\% \qquad (1)$$

Now the typical q-factor is 0.67 and expected to become 0.87 due to further development that can be expressed in Fig. 7. The electricity yield E_{pv} from PV systems is calculated by the following equations taking into consideration the capacity factor of PV power plant as a function of the average annual irradiance on the surface as given:

$$E_{PV} = P_{PV} CF_{PV} 8760\ h/y,$$

$$CF_{PV} = q_{PV} GTI \eta_{PV} A_{PV} / 8760\ h/y \qquad (2)$$

where E_{PV} is annual electricity yields from PV (kWh/y), CF_{PV} is capacity factor as function of the annual global irradiance, P_{PV} is installed PV power capacity (kW), q_{PV} is annual system efficiency/standard design efficiency, GTI is global irradiance on a tilted surface (kWh/m²/y), η_{PV} is annual PV system efficiency in first year (assumed as $\eta_{PV} \sim 0.1–0.3$), A_{PV} is design collector area for standard efficiency (m²/kW) ($A_{PV} = 10$ m²/kW) and 8760 represents the total hours per year.

3.7. Concentrating solar thermal power and solar chimneys

The CSP is based on the concept of concentrating the solar radiation on a heated cavity which contains absorbing boiler to convert the liquid media temperature into a higher temperature in order to convert liquid water into a dry steam above 400 °C for a steam turbine. The system uses glass mirrors that continuously track the position of the sun to concentrate the sun radiation. The heat transfer fluid can be oil, or molten salt or may be water and air used directly to drive the turbine. This installation may be parabolic trough, linear Fresnel and power towers could be coupled to steam cycles of 5–200 MW of electrical capacity, with thermal efficiency of 30–40%. The Dish-stirling engine is used in a decentralized generation in the 10 kW range within efficiency of 18% while other efficiency has the same as that of steam power plant. However, the relative performance of each of the various CSP technologies is given elsewhere [30,31] as seen in Table 14. To generate 1 MWh of solar electricity per year, a land area of 4–12 m² is required. This means km^2 needs land can continuously and indefinitely generate as much electricity as any conventional 50 MW coal – or gas fired power station. The CSP technology can

Table 13
Some characteristics of contemporary power technologies [3].

	Unit capacity	Capacity credit	Capacity factor	Resource	Application	Comment
Wind power	1 kw–5 Mw	0–30%	15–50%	Kinetic energy Of the Wind	Electricity	Fluctuating supply defined by resource
Photovoltaic	1 W–5 Mw	0%	15–25%	Direct and diffuse irradiance on a fixed surface tilted with latitude angle	Electricity	Fluctuating supply defined by resource
Biomass	1 kw–25 Mw	50–90%	40–60%	biogas from the decomposition of organic residues, solid residues and wood	Electricity and heat	Seasonal fluctuations but good storability, power on demand
Geothermal	25–50 MW	90%	40–90%	heat of hot dry rocks in several 1000 m depth	electricity and heat	No fluctuations, power on demand
Hydropower	1 kW–1000 MW	50–90%	10–90%	kinetic energy and pressure of water streams	electricity	Seasonal fluctuation, good storability in dams, used also as pump storage for other sources
Solar chimney	100–200 MW	10–70% depending on storage	20 to 70%	Direct and diffuse irradiance on a horizontal plane	electricity	Seasonal fluctuations, good storability, base load power
Concentrating solar thermal power	10 kW–200 MW	0–90% depend on storage and hybridisat-ion	20 to 90%	Direct irradiance on A surface tracking the sun	electricity and heat	Fluctuations are compensated by thermal storage and fuel, power on demand
Gas turbine	0.5–100 MW	90%	10–90%	natural gas, fuel oil	electricity and heat	power on demand
Steam cycle	5–500 MW	90%	40–90%	coal, lignite, fuel oil, natural gas	electricity and heat	Power on demand
Nuclear	1000 MW	90%	90%	uranium	electricity and heat	Base load power

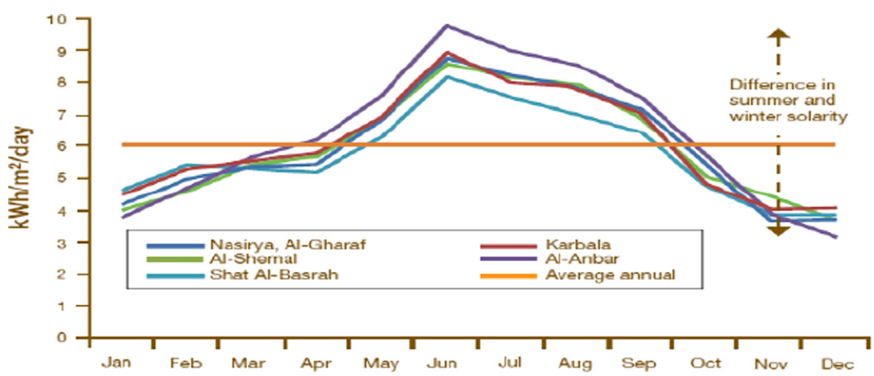

Fig. 6. Monthly averaged direct radiation for selected site in Iraq and the difference between summer and winter solarity in Iraq [26].

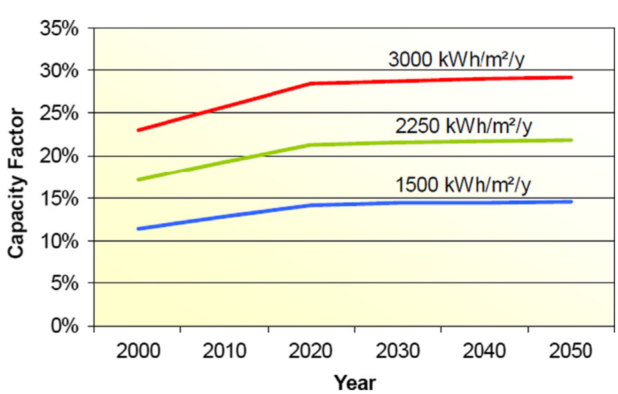

Fig. 7. An Outlook Capacity factor of grid-connected PV systems as function of global irradiance [29].

be operated with thermal energy storage or combined and co-fired with natural gas with a capacity credit and availability of 90% like conventional power plant, and can produce up to 600 MW capacity. CSP is an electrical generation fueled by the sun heat, an endless source of clean, free energy. Miqdam et al. [32] have studied the feasibility of improving CSP plant efficiency. By manufacturing 3-D prototype, coloring the central target with a selective black color and fixing a reflector with arc form behind the target. The tests were conducted at Iraqi weathers in spring-time (March, April and May) and summertime (June, July and August) of 2012. They have concluded that the Iraqi weathers are suitable for this type of systems. It is possible to attain high target temperatures which can operate power station. The heat storage capacity and fousil fuel rate are:

$$E_{CSP} = P_{CSP} CF_{CSP} 8760 = E_{solar} + E_{fossil} \quad (3)$$

where E_{solar} is annual solar electricity yield (MWh/y), E_{fossil} is annual fossil electricity yield (MWh/y), CF_{CSP} is capacity factor as function of load, P_{CSP} is installed capacity (MW).

The solar chimney is considered as solar thermal power plant consisting of very large glass roof with a high chimney in the center. Then air underneath the glass housing heated up and due change in density drives its way out to chimney where it activates a wind turbine for power generation in the range of 100–200 MW capacity. In Iraq, a practical prototype model of the solar chimney

Table 14
Performance data of various concentrating solar power (CSP). technologies [30,31].

CSP type	Capacity unit MW	Concentration	Solar efficiency peak	Annual solar efficiency	Thermal cycle efficiency	Capacity factor solar	Land use m^2/MW/year
Trough	10–200	70–80	21%[d]	10–15%[d] 17–18%[p]	30–40%[ST]	24%[d] 25-90%[p]	6–8
Fresnel	10–200	25–100	20%[p]	9–11%[p]	30–40%[ST]	25-90%[p]	4–6
Power tower	10–150	300–1000	20%[d] 35%[p]	8–10%[d] 15–25%[p]	30–40%[ST] 45–55%[CC]	25-90%[p]	8–12
Dish-stirling	0.01–0.4	1000–3000	29%[d]	16–18%[d] 18–23%[p]	30–40%[Stir.] 20–30%[GT]	25%[p]	8–12

[d]: demonstrated, [p]: projected, [ST]: steam turbine, [GT]: Gas Turbine, [CC]: Combined Cycle. Solar efficiency: net power generation/incident beam radiation, Capacity factor: solar operating hours per year/8760 h/year.

power plant was designed and constructed [33]. The effects of storage parameter, such as the solar radiation, the ambient temperature, and the heat storage capacity for ground materials on the power plant operation time are investigated. According to the obtained results, such systems are fitted to Iraqi weathers.

3.8. The hydropower status in Iraq and future trends in developed energy

As mentioned earlier to the state of hydropower that has capacity of 5.1 GW and running at 1.5–2.5 GW due to lack of maintenance and grid losses, where the targeted is 20 GW. The targeted hydropower is around 20 GW which distributed at Haditha 660 MW, Mousil 750 MW, Samara 75 MW, Erbil Dokan Dam 400 MW, the Sulaiymanya Durbenkhan 240 MW. The other targeted Halwan 52 MW, Dohuk and Gali Balinda 111 MW are partially operation and/or partial stoppage. This can be extended further in future. The cost of generating 1 MW mounted to 2 Million US Dollar, but there are vast potential in the western desert where many dry valleys flooding during winter and dried up in summer which serve a strategic water reservoir for energy storage dam to serve the renewable energy from PV or CSP to maintain stable supply. The hydropower should also foresee as power storage for which no planning for cycling reservoir yet.

$$E_{hydro} = P_{hydro} CF_{hydro} 8760\ \text{h/y} \tag{4}$$

where E_{hydro} is annual electricity yield from hydropower plants (MW h/y), CF_{hydro} is capacity factor (from existing hydropower plants of a country), P_{hydro} is installed hydropower capacity (MW).

Recently, there is no exact study of hydropower impact on the quantity of river water and the losses by evaporation that may affect the environment or reduction of water supply to the downstream agricultural plantation or livestock as well as the potable water for human needs. The capacity credit and availability are 90% and may be reduced by 25% [34–36]. The other source of renewable energy is not mentioned here namely the biofuel, the geothermal which is yet far from applicability due to political and public unawareness but may be an issue in future.

3.9. The energy question of renewable energy at the presence of oil and gas in Iraq

On observing the large amount of oil and gas available in Iraq, it is still not being conclusive yet, the exact amount of oil fields that being discovered especially in the southern desert bahar Alnajaf down to the southern border [37]. The productivity with multi-story oil fields that not being yet estimated and export are given in Fig. 8. The domestic usage of oil and gas can be characterized as shown in Fig. 9. Due to huge amount of gas being flared all together with other activity to share CO_2 emission in Iraq, the fossil fuel consumption can be distributed on the basis on various activities as shown in Fig. 10. Other demands on fossil fuel consumption is required, while no infrastructure planned yet for public mass transport to be seen in the near future as well as no public awareness focuses on other mean of transport such as an electrical cars. The energy sector and other activity have a trend of expansion and investment on fossil fuel consumption rather than taking into account the future trend for an energy share and further expansion into renewable energy form to replace the present dominant fossil fuel consumption that may expand to other sector. This should be passed on planning to share renewable type of electricity generation to reduce the dependence on fossil fuel. This planning should be considered now as the valuable abundance of solar power availability as previously mentioned. The renewable energy share can be seen from PV, CSP plant or mixed, hydropower and may be wind and biomass.

4. Conclusion

The energy question in Iraq has suffered since 1958 onward due to geopolitical of indefinable goals for the people needs, wellbeing development and their interest. The resulted outcome has only to maintain the existing infrastructure of what already being built with no further development in the field of oil, gas production and marketing as well as the electrical energy for industrial activities. The electricity generation has a setback since 1991 due to wave of destruction of major thermal generating stations, while in 2003 another major disruption and sabotage have started with further shortages of electrical power supply. The shortages cause daily blackout maintained for more than 18–8 h minimum. However, the cost of repair and running of this aging power plant become more than the cost of refurbishing and may build a new plant of capacity 9 GW. However, the availability of hydropower with generating capacity 5.1 GW was due to bad management and lack of maintenance running at about 1.5 GW and its grids suffer loss of 49% according to the World Bank report. This handicap has been maintained for the last decade and may stay on for the next decade due to vast energy requirements in oil industry and productions. Therefore, it becomes necessity for vast investment to develop the solar energy infrastructure in terms of shared or localized plants with viable storage capacity to serve the growing demands. So, the hydropower may has great potential if friendly environment hydropower has to be considered. It is inconceivable that the produced gas goes into flares, while huge amount of gas being imported for local consumption. This is damaging source to the environment as well as loss of energy source which is world responsibility rather than the worst Iraqi oil management and oil companies. Furthermore, the most viable resources is the fresh water from the giant rivers of Tigris and Euphrates that require

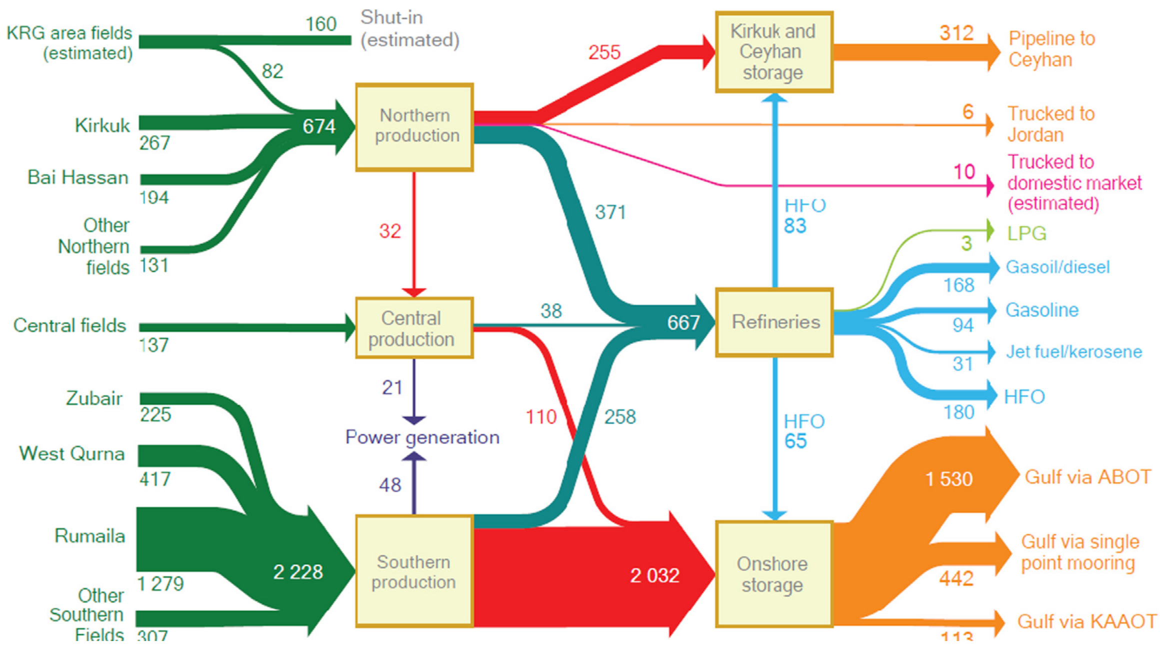

Fig. 8. Iraq average daily oil production and transportation, June 2012 [37].

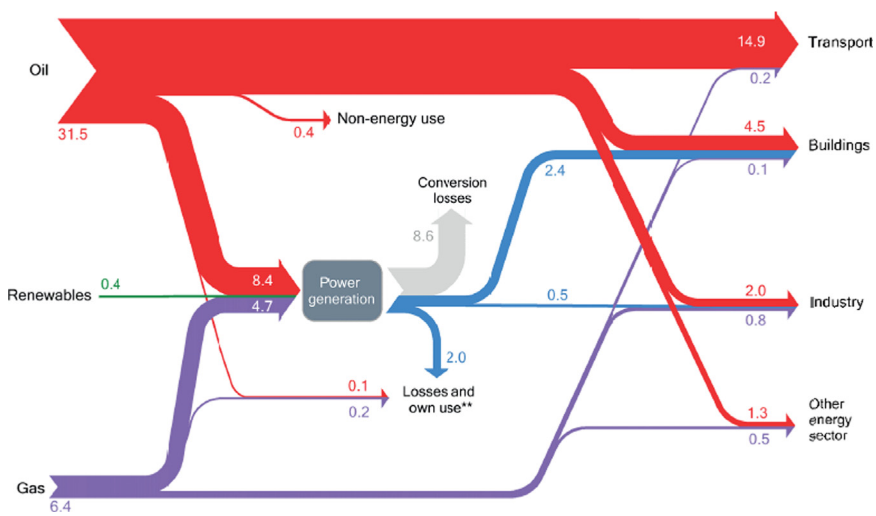

Fig. 9. Iraq domestic energy balance, 2010 [37].

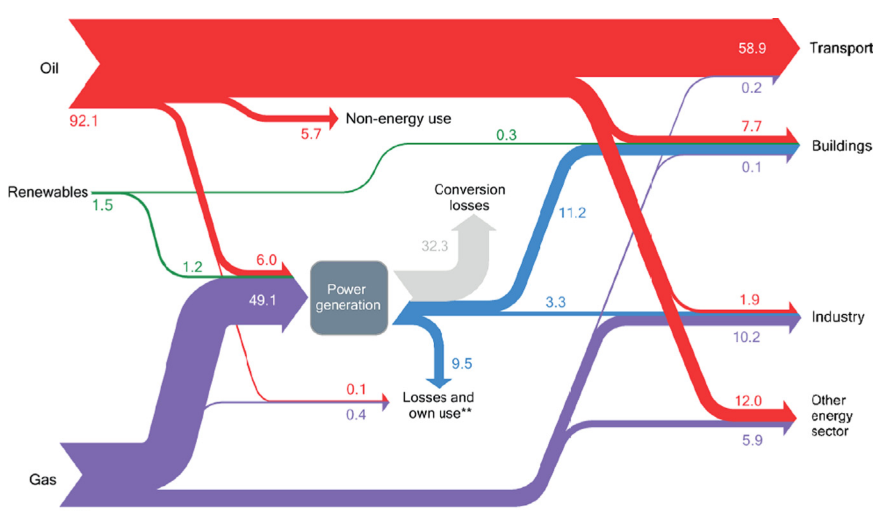

Fig. 10. Iraq domestic energy balance in the best Scenario, 2035 [37].

safe guard from the pollution in the coming years due to production increasing of crude oils and scattered refineries which are constructed less than high standard. All these activities are source of CO_2 emission, renewable solar energy and environment friendly hydropower to fulfill the electrical power of the country requirements as a solution to reduce CO_2 emission.

References

[1] Jacobson MZ, Howarth RW, Delucchi MA, Scobie SR, Barth JM, Dvorak MJ, et al. Examining the feasibility of converting New York State's all-purpose energy infrastructure to one using wind, water, and sunlight. Energy Policy 2013;57:585–601.

[2] Hernandez RR, Easter SB, Murphy-Mariscal ML, Maestre FT, Tavassoli M, Allen EB, et al. Environmental impacts of utility-scale solar energy. Renew Sustain Energy Rev 2014;29:766–79.

[3] Feltrin A, Freundlich A. Material considerations for terawatt level deployment of photovoltaics. Renew Energy 2008;33:180–5.

[4] Sørensen B. Renewable energy: its physics, engineering, use, environmental impacts, economy and planning aspects. Roskilde University; 2004.

[5] Kazem HA, Chaichan MT. Status and future prospects of renewable energy in Iraq. Renew Sustain Energy Rev 2012;16:6007–12.

[6] Dihrab SS, Sopian K. Electricity generation of hybrid PV/wind systems in Iraq. Renew Energy 2010;35:1303–7.

[7] AL-Riahi M, AL-Kayssi A. Some comments on time variation in solar radiation over Baghdad, Iraq. Renew Energy 1998;14:479–84.

[8] AL-Riahi M, AL-Hamdani N, AL-Saffar H. Some aspects of solar radiation climatology of Iraq. Renew Energy 1992;2:167–73.

[9] Abbas MA, Elnesr MK. Cloudiness and estimation of incoming solar radiation in Iraq. Pure Appl Geophys 1973;112:234–9.

[10] Al-Salihi AM, Kadum MM, Mohammed AJ. Estimation of global solar radiation on horizontal surface using routine meteorological measurements for different cities in Iraq. Asian J Sci Res 2010;3:240–8.

[11] Al-Riahi M, AL-Kayssi A. Some comments on time variation in solar radiation over baghdad, Iraq. Renew Energy 1998;14:479–84.

[12] Abed FM, Al-Shahery GhYM. Estimation of global solar radiation on horizontal surfaces over Haditha, Samara, and Beji, Iraq. Pac J Sci Technol 2010;11:73–82.

[13] Majeed AJ. Empirical models for correlation of clearness index with cloud index at Rutba, Iraq State. Int J Eng Res Appl 2013;3:1189–92.

[14] Salih SM, Salih FF, Hasan ML, Bedaiawi MY. Performance evaluation of photovoltaic models based on a solar model tester. Int J Inf Technol Comput Sci 2012;7:1–10.

[15] Rahoma UA. Utilization of solar radiation in high energy intensive of the world by PV system. Am J Environ Sci 2008;4:121–8.

[16] Abed FM, Mohammed GHY. Empirical models for the correlation with sunshine duration of metrological data for Tikrit-TuzKhurmato and Kirkuk-Iraq. Tikrit J Eng Sci 2012;19:1–13.

[17] Toğrul IT. Estimation of solar radiation from angstroms coefficients by using geographical and meteorological data in bishkek, kyrgyzstan. J Therm Sci Technol 2009;29:99–108.

[18] Musa B, Zangina U, Aminu M. Estimation of global solar radiation in maiduguri, nigeria using angstrom model. J Eng Appl Sci 2012;7:1623–7.

[19] Ogolo EO. Evaluating the performance of some predictive models for estimating global solar radiation across varying climatic conditions in Nigeria. Indian J Radio Space Phys 2010;39:121–31.

[20] Angstrom A. Solar and terrestrial radiation. Q J R Meteorol Soc 1924;50:121–6.

[21] Abdul-Wahid SN, Hassan AM. Calculation and applications of net solar radiation in Iraq. J Al-Qadisiyah Pure Sci 2010;15:1–30.

[22] Breeuwer Jelco, Energy use and CO_2 emissions of consumer goods transport, trends of Dutch imports in the period 1969–2010, Center for Energy and Environmental Studies, University of Groningen; 2012.

[23] Balaguer IJ, Lei Q, Yang S, Supatti U, Peng FZ. Control for grid-connected and intentional islanding operations of distributed power generation. IEEE Trans Ind Electron 2011;58:147–57.

[24] Allen MS, Hazlett N, Nerlinger S, Matt. Smart grid: the next infrastructure revolution. New York: Morgan Stanley; 2009.

[25] Khaldoun S, Al-Bassam M, Mahdi MA, Al-Delaimi MR. Contribution to the origin of the syngenetic uranium enrichment in the early miocene carbonates of the Euphrates formation. Iraq Geol Surv 2006;2:1–21.

[26] Abed Fayadh M, Alshahery Ghazy M. Comparative simulation of different nanoparticles concentration with respect rectangular heat transfer tube. Int J Nanoelectron Mater 2012;5:101–16.

[27] Lenert A, Wang EN. Optimization of nanofluid volumetric receivers for solar thermal energy conversion. Solar Energy 2012;86:253–6.

[28] de Risi A, Milanse M, Laforgia D. Modeling and optimization of transparent parabolic trough collector based on gas phase nanofluid. Renew Energy 2013;58:134–9.

[29] Sissakian VK, Abdul Ahad AD, Hamid AT. Geological hazards in Iraq, classification and geographical distribution. Iraqi Bull Geol Min 2011;**7**:1–28.

[30] Roeb M, Müller-Steinhagen H. Concentrating on solar electricity and fuels. Science 2010;329:773–4.

[31] Kroposki B, Margolis R, Ton D. Harnessing the sun: an overview of solar technologies. IEEE Power Energy Mag 2009;7:22–34.

[32] Chaichan MT, Khalil IA, Kazem HA. The effect of variable designs of the central receiver to improve the solar tower efficiency. Int J Eng Sci 2012;1:56–61.

[33] Chaichan MT, Kazem HA. Thermal storage comparison for variable basement kinds of a solar chimney prototype in Baghdad – Iraq weathers. Int J Appl Sci 2011;2:12–20.

[34] Omer MA, Ahmed SA, Al-Jumaily KJ. Solar cycle forcing on Kurdistan-Iraq. J Zankoy Sulaimani Part A 2013;15:43–55.

[35] Birolm F, Argiri M. World energy prospects to 2020. Energy 1999;24:905–18.

[36] Rojanamon P, Chaisomphob T, Bureekul T. Application of geographical information system to site selection of small run-of-river hydropower project by considering engineering/economic/environmental criteria and social impact. Renew Sustain Energy Rev 2009;13:2336–48.

[37] Sissakian VK, Ajar D, Zaini MT. Karstification influence on the drainage system examples from the Iraqi southern. Iraqi Bull Geol Min 2012;8:99–115.